Supplier evaluation with order allocation in mega-projects

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Abstract

Purpose- The purpose of this study is to provide a model for evaluating, prioritizing and allocating orders to suppliers in the supply chain for mega-projects.
Methodology- By using an integrated model (based on Fuzzy Analytic Network Process (FANP)), suppliers are selected and the appropriate amounts are allocated to them in mega-projects. Initially, a hierarchical model of the research method was introduced. Then, the results on reliability and validity analysis of research measurement tools were presented. Finally, prioritization and allocation of orders to suppliers, with a case study of Iran Mall project, was carried out using Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP). T-test was employed to evaluate the research hypotheses.
Findings- The findings were examined against conventional numerical analysis techniques. Finally, implication and recommendations for future work were presented.
Keywords: Supplier Selection, Supply Chain, Allocating order to suppliers, FANP, Prioritization.

1. Introduction

Nowadays, Supply Chain Management (SMC) is one of the infrastructures in implementing all kinds of businesses in the world. Customers demand for high quality and fast service has added to the new challenges. As a result, companies can no longer handle all the tasks on their own.

Mega construction projects are typically very complicated in nature. The evaluation and comprehension of their complexities remain vital to their success. Empirical research related to the calculation of megaproject difficulty handling, however, remains under-studied (He et al., 2015). SCM must be recognized in mega-projects beyond their operational and technical complexities to evaluate expanded project criteria and new market conditions. Therefore, it is important to identify and analyze the complexities of mega projects, as they directly affect project performance (Baccarini, 1996; Eriksson and Pesämaa, 2013; Houston, 2014; Wang et al., 2017).

Many managers know that actions taken by one member of the chain can affect the profitability of all other components. Companies often think of competing with other supply chains as part of the supply chain itself. They do not compete with their own supply chain components. The cost associated with poor coordination between these components can be extremely high. In this context, the issue of identifying and managing the risks in the aforementioned cycle is of utmost importance (Hosseini, 2012).

This research provides a framework to evaluate suppliers based on some conditions and constraints. The supplier and carrier were selected with an overview approach under a unified decision-making paradigm. Therefore, for many companies, industrial and non-industrial alike, that are somehow faced with supplier and carrier selection, the proposed research can be useful. In this research, a model for supplier selection in large projects is implemented using multi-criteria decision-making method and fuzzy approach.

Here is the layout of the paper. First, an introduction is presented and then a theoretical framework of research is provided. In the next steps, the research method, the results, and finally the conclusions and managerial implications are presented.

2. Literature Review

In today's competitive marketplace, business owners need to provide their customers with the best quality, services or goods in the shortest time and under the least cost to be able to remain competitive. A strong and efficient supply chain for competition is essential (Sajadieh and Akbari, 2008). Under these circumstances, the role of suppliers is of great importance. Generally, the most important aspect of the supplier selection is to identify suppliers. They consistently have the highest potential to meet the needs of a company at an acceptable cost. This selection is naturally made possible by a broad comparison of suppliers based on a set of criteria (Razmi and Nasrollahi, 2013). Supplier selection is one of the most important decision-making processes. Their overall purpose is to reduce purchase risk, to maximize total buyer value, and to establish a close and long-term relationship between buyers and suppliers (Asadi and Zagardi, 2008).

Particularly, mega-projects require many raw materials, components and goods from suppliers. So, the role and position of suppliers in the project supply chain is increasingly emphasized and in the success of mega projects is vital. To achieve the right supply chain, the process of evaluating, selecting and continually improving suppliers must be exercised. The costly and time-consuming process of selecting suppliers on one hand, and the growing capabilities of ICTs on the other, have driven organizations to move toward developing backup systems (Fawcett, 2014).

One main reason for the importance of the supplier selection problem is that the price cannot be regarded as the sole criterion of supplier selection. The supplier selection problem is a multi-criterion decision-making (MCDM) problem involving various quantitative and qualitative variables (Sarabi and Darestani, 2020). The issue of supplier selection and evaluation is one of the most important issues in SCM. Supplier selection involves measuring and analyzing the performance of a set of suppliers in order to rank them to improve the competitive situation of the entire supply system (Sevkli, 2008).

2.1 Supplier Selection

Selection methods of suppliers are models or methods that are used to execute the selection process. The methods selected during this process greatly influence the outcome. Usually, when a company decides to select or develop a supplier selection method, the result consists of a combination of different approaches. They are created according to the needs of the company. Therefore, it is important to understand the different approaches to understanding the applications of each in different areas (Asfora Frej et al., 2017).

There are various methods cited in the supplier selection history, including linear weighting models, in which case weights are assigned to suppliers for different criteria, and then by combining these weights. Each supplier gets the overall score. This model is a simple method that acts based on the classification of criteria, and is considered the fastest, easiest, and least costly method to implement. However, it relies heavily on manpower and that it is not a very accurate method (Aouadni et al., 2019)

Choosing the right supplier requires criteria and indicators for supplier evaluation that have been investigated and identified in different researches. Summary of criteria used in the pertinent research are: product quality, service, supplier flexibility, price of products or services, delivery process, delivery time, response to changing demand, supplier manufacturing capability, technical capability and stable delivery (Suraraksa and Sup Shin, 2019). Due to price fluctuations and high inflation in Iran, delivery time and prices are usually not definitive during the cooperation period (Biranvand et al., 2016). Therefore, this study tries to use these criteria and indicators in evaluating and selecting a supplier.

2.2 Supplier Evaluation Criteria

With the increasing importance of purchasing and logistics activities, purchasing decisions have become more important. As organizations become more dependent on suppliers today, the direct and indirect consequences of poor decision-making become worse. In most industries, the cost of raw materials and product components accounts for the bulk of the cost (Zazulina, 2010).

In such situations, the procurement department can play a key role in the efficiency and effectiveness of the organization. In fact, choosing the right set of suppliers for a company to succeed is crucial. In this way, having appropriate and useful criteria for evaluating suppliers is very important and vital. It can play an important role in achieving the goals of the organization. Usually, the most important goal of choosing a supplier is to identify the suppliers who consistently have the highest potential to meet the needs of a company at an acceptable cost (Cheraghi et al., 2011). Some researches in this field can be summarized in Table 1:

Table 1. Indicators for selecting suppliers in the research done

Authors		Kreng & Wang	Wang et al	Govindan et al	Chang et al	Ávila et al	Liou et al	Asadabadi	Azimifard	Abbaszadeh Tavassoli et al	Liang and Chong	Mahmoudi et al
Year		2005	2009	2010	2011	2012	2014	2017	2018	2018	2019	2020
Criteria	Quality	X	X	X	X	X	X	X	X	X		X
	Service		X		X			X		X		X
	Flexibility						X	X	X			
	Price		X	X	X	X	X	X	X	X		
	Delivery	X	X	X			X		X	X		
	Delivery interval	X							X			
	Reacting to changing demand		X									
	Production capability			X		X		X				
	Technical capability			X				X				
	Stable delivery	X										
Method	Decision making		X		X	X	X	X	X	X	X	X
	Mathematical program	X	X									
	Others			X				X				
Environment	Mega										X	X
	Others	X	X	X	X	X	X	X	X	X		

2.3 Research Background

The research on the supplier selection process is vast. Gaballa was the first researcher to apply mathematical programming to supplier selection in a real case in 1974. He used mixed-integer programming to minimize the total cost of items assigned to each supplier. He also developed a mixed one-goal integer programming to minimize purchasing, inventory and shipping costs, taking into account multiple items, multiple periods, quality, delivery and capacity (Eamon, 1998).

Wang et al. (2007) developed a decision-making methodology for the supply chain that enables the plant manager to select the right suppliers. In this methodology, Analytic Hierarchy Process (AHP) techniques and ideal planning are used. Sarkis & Talluri (2008) provided a model for supplier evaluation that ranked factors based on ANP. Lee (2009) used a hybrid approach including AHP and fuzzy multi-objective programming to select suppliers. This research presents a comprehensive model that considers the four merits simultaneously. Also, fuzzy set theory is incorporated into the model to overcome the uncertainty and ambiguity in human decision-making process. Weber & Ellram (2009) used a hybrid optimization approach, including multi-objective programming and Data envelopment analysis (DEA) approach. In this approach, multi-objective programming was first used to select suppliers. Then, the DEA approach was used to evaluate the efficiency of the selected suppliers based on several criteria. The objective of study of Kokangul & Susuz (2009) was to develop a multi-product linear multi-objective model for the supplier selection problem with a discount. The fuzzy Zimmerman approach is used to solve the above problem due to the uncertainty and flexibility of decision-making. Ho et al. (2010), reviewed 70 articles on data envelopment analysis methods and AHP. He has introduced integrated approach of goal programming with AHP method as the most commonly used methods in selecting logistics providers. Ghodsypour and Obrien (2010) created a decision support system to reduce the number of suppliers based on the supply base optimization strategy. He used a hierarchical integer analysis process with mixed integer programming and considered supplier capacity constraints and budget constraints and buyer quality. Amid et al. (2011) developed a multi-objective mixed integer programming approach. They simultaneously determine the number of suppliers and the amount of order assigned to each in a multi-source multi-product source environment. Shaw et al. (2012) examined suppliers using Fuzzy AHP (FAHP) and then applies Fuzzy Multi-Objective Programming to supplier selection. Bottani and Rizzi (2012) used Fuzzy TOPSIS approach to rank and selected the best third party logistics. They used nine criteria in the proposed approach including compatibility, financial stability, flexibility of service, performance, price, physical equipment and information, quality, strategic attitude, trust and fairness. Efendigil et al. (2013) has been proposed a hybrid approach of fuzzy AHP and artificial neural networks in order to optimize the logistics of the third party. They consider twelve factors in the decision-making process: on time delivery, confirmed fill rate, service quality, unit operation cost, capacity usage, total order cycle time, system flexibility index, integration level, increment in market share, research and development, environmental expenditures, customer satisfaction. Senvar et al. (2014) explained the supplier selection process to reduce purchase risk, maximize value for the customer, and created a close relationship between buyer and supplier. Du et al. (2015) investigated the issue of supplier selection and order allocation in multi-product mode with multiple suppliers in a supply chain. In the proposed model, the three objectives were to minimize the total cost of purchase by considering the fixed costs of minimizing the number of returned products and minimizing the number of delivery delays. The main objective was also to reduce the total production cycle time. Prassana et al. (2016) presented a model that minimizes the risk of disruption and delay in obtaining a supplier by minimizing the costs associated with purchasing and ordering to the supplier. Hamdan et al. (2017) chose supplier and order allocation taking into account green indicators. In this research, he used a hybrid approach of multi-criteria programming and multi-objective programming to select and allocate orders to the supplier.

2.4 The novelty of this work

Mega-projects are large-scale, complex ventures that cost a billion dollars or more, take many years to develop and build, include multiple public and private stakeholders, are transformational, and affect millions of people (Flyvbjerg, 2014). Mega-projects are temporary activities (i.e. projects) characterized by large investment commitment, vast complexity (especially in organizational terms), and long-lasting effect on the economy, the environment, and society (Locatelli et al., 2017).

Mega-projects have a widespread effect at the surroundings and need to be controlled efficiently (Mahmoudi et al., 2020). These projects are normally very complex in nature. Because of missing applicable knowledge, they are generally beset with low performance, including such as cost overruns and schedule delays (He et al., 2015). Also, mega-projects have considered certain criteria in selecting and evaluating suppliers for their environmental performance (Hlioui et al., 2017; Liang and Chong, 2019). Researchers and specialists have long explored for ways of progressing "project success" in these mega-projects. They contended that the prevalence of project failures may be due to the problems related with traditional project management theory (Chang et al., 2013). Lack of correct planning for material processing and supply chain operation is led to problems (Golpîra, 2020). Many researches have studied supply chain using various methods. Lee (2009) established a hybrid approach including AHP and fuzzy multi-objective programming for selection of suppliers. Shaw et al. (2012) proposed FAHP and then applies fuzzy multi-objective programming to supplier selection. Qu et al. (2020) explored green supplier selection based on green practices using fuzzy approaches of TOPSIS and ELECTRE. Mahmoudi et al. (2020) explored sustainable supplier selection using Ordinal Priority Approach (OPA) in mega-projects.

The novelty of this research is using hybridization of decision-making techniques and optimization modeling for mega-projects that have not been done in previous researches. Given the aforementioned, this research seeks to answer the question of how to allocate orders to suppliers in the supply chain of large construction projects? To this end, this research seeks to select suppliers and the appropriate amounts allocated to them in mega-projects using an integrated model (ideal and FANP). This study will have a strong practical value in deciding the supplier selection method during the decision-making process in megaprojects.

3. Methodology

The present study is an applied research in terms of the nature. Method used for data collection, can be classified as a descriptive (non-experimental) method. Also, the survey type adopted in this study, is cross-sectional. The statistical population consists of managers and experts of the Iran Mall Project. Since this study is used by experts, whose numbers are limited, so the census method is used. The method of data collection is library and field. In this research, the theoretical bases and background of the research are collected through library, article and internet. They used as deductive reasoning in rejecting or proving research hypotheses using appropriate statistical methods. The field method is used to collect the data and information needed to investigate the research variables and test the hypotheses. Therefore, tool of the data collection in this study is a paired comparison questionnaire.

One of the solution method used in this paper is DEMATEL. DIMATEL technique is one of the decision-making methods based on pairwise comparisons. It creates a paired comparison matrix and then use a specified range to score. It is also the basis for determining the influence of the views of experts (Keskin, 2014).

One of the benefit using DEMATEL is that the criteria interact with each other. This method not only converts the interdependency relationships into a cause and effect group via matrixes but also finds the critical factors of a complex structure system with the help of an impact relation diagram (Si et al., 2018). So, there is still a spectrum of linguistic expressions from "no influence" to "very high influence" that is shown in Table 2.

Table 2. Linguistic spectrum of scale to the Linguistic phrase in the questionnaire

Linguistic variable	Definitive Scale	Fuzzy Scale (a)	Fuzzy Scale (b)
No influence	0	(0, 1.0, 3.0)	(0, 0, 25.0)
Low influence	1	(1.0, 3.0, 5.0)	(0, 25.0, 5.0)
Moderate influence	2	(3.0, 5.0, 7.0)	(25.0, 5.0, 75.0)
High influence	3	(5.0, 7.0, 9.0)	(5.0, 75.0, 1)
Very high influence	4	(7.0, 9.0, 1)	(75.0, 1, 1)

Also, this work used the FANP approach to degree inter correlation of the assessment standards. The ANP does not need a hierarchical structure, since depict the consequences in relationships between decision-making levels in a grid and consider interactions and feedbacks between criteria and alternatives (Najar Vazifehdan and Avakh Darestani, 2019). The ANP considers complex relationship among decision elements by replacement of sequential structure with network structure. Advantage of ANP technique compared to other techniques is considering internal relations among factors (Farshchian et al., 2020).

3.1 Validity and reliability of data collection tools

To ensure the validity of the present study, a structured questionnaire was obtained through study of books, thesis and related articles and backgrounds as well as expert opinions. Its validity is examined using the content. Therefore, the questionnaire was submitted to five professors and five industry experts. After repeated reviews and revisions by professors and experts, the necessary recommendations were made to correct, remove and add a number of questions until the final questionnaire was prepared.

To evaluate content validity quantitatively, two indices, namely the content validity ratio (CVR) and content validity index (CVI) were used. The CVI will calculate the cumulative points agrees for each item that has received "relevant but need review" and "fully relevant" points divided by the total number of experts. In order to determine the CVR, experts were asked to evaluate each item on a three-point scale, "necessary", "useful, but not necessary" "not necessary", and then calculate the answers according to Equation (1) (Najar Vazifehdan and Avakh Darestani, 2019).

$$CVR = \frac{n_E - \frac{N}{2}}{\frac{N}{2}} \quad (1)$$

Where, n_E is the number of experts who responded to the "necessary" option and N denotes the total number of experts. If the calculated value is greater than the table value, the item's content validity will be accepted. Validity of each item is shown in Table (3).

Table 3. Validity of each item

Number of experts	Minimum validity
5	99.0
6	99.0
7	99.0
8	85.0
9	78.0
10	62.0
15	49.0
20	42.0
25	37.0
30	33.0
40	29.0

In this study, Cronbach's alpha test (α) was used to evaluate the reliability of the designed questionnaire. All Cronbach's alpha values are greater than 0.7. So, the questionnaire is reliable.

3.2 Data Analysis

The evaluation process is multidimensional in nature. Both quantitative and qualitative variables must be considered in the evaluation process. In addition, there are various variables within the relationship system. The ANP technique considers these requirements as a precise approach in modeling complex decision-making problems by converting qualitative judgments into quantitative values and then by observing the relationships of various factors. Because human judgments about preferences are often vague, and they cannot be represented by exact numbers, a fuzzy logic approach to deal with data was adopted (Penadés-Plà et al., 2016). The FANP was used as the method of choice to create the decision tools in this study.
The present study is conducted using two methods of ANP network analysis and the DEMTEL technique. Initially, using ANP network analysis method, the weight of each selected supplier's criteria is determined and identified. Then, the suppliers are ranked using the weight calculated in the previous step using the DEMATEL technique.

3.2.1 Analytic Network Process (ANP)

The ANP, which is derived from the well-known AHP, can quantitatively measure inter-relation of factors and parameters in a holonomic system (Saaty, 1996). The proposed model in this study focuses on the structure of the partnership pyramid and the selection process is transformed into a four-step bonding process (Figure 1).
Step 1: Selecting the criteria for prioritizing effective indicators.
Step 2: Identifying the dependency between criteria.
Step 3: Calculating weights for criteria.
Step 4: Ranking options and indicators.

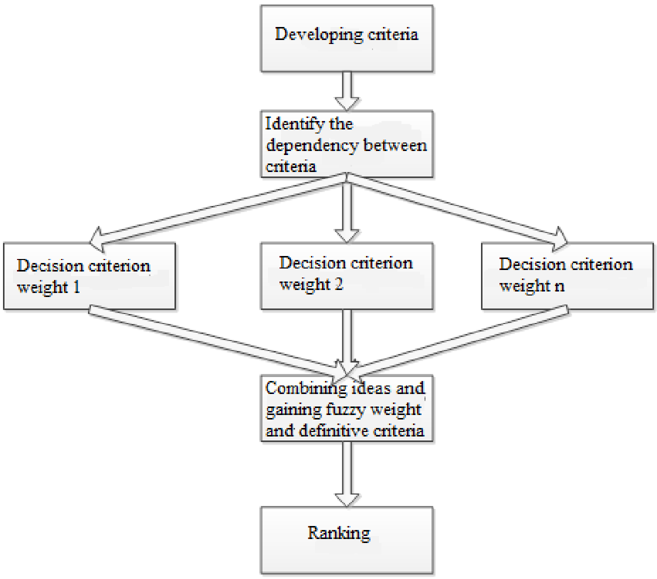

Figure 1. ANP flowchart

The ANP (developed as AHP) is used to determine the relationship between the degrees of dependency. It is specified as a measure of relative importance of all criteria used. This has been developed to provide a more realistic set of conditions for decision-making without making any presumptions about the one-way hierarchical relationship between decision levels.

Experts or decision makers were asked to evaluate all proposed criteria through pairwise comparisons, regardless of the assumptions of interdependencies. Fuzzy sets were then used in this study. Since, they were more compatible with linguistic and sometimes ambiguous human explanations. It is better to use long-range prediction and real-world decision-making using fuzzy sets (applying fuzzy numbers). The FANP is an efficient tool to deal with the fuzziness of data on different decision variables (He et al., 2015). Since the numbers used in this method are triangular fuzzy numbers, the fuzzy scales used in the fuzzy hierarchical analysis process are as follows:

Triangular fuzzy number calculation: given the relative importance of the values calculated in the previous step, triangular fuzzy numbers are computed to integrate all expert opinions. The set of triangular fuzzy numbers is defined as follows:

$$\tilde{a}_{ij} = [\alpha_{ij}, \beta_{ij}, \delta_{ij}] \quad (2)$$

$\tilde{a}_{ij}$ is the set of triangular fuzzy numbers, α_{ij} is the minimum value of criterion j for dimension i, β_{ij} is the geometric mean of criterion j for dimension i and δ_{ij} is the maximum value of criterion j for dimension i.

Fuzzy positive reciprocal matrix: The matrix set derived from the fuzzy set is as follows.

$$\tilde{a}_{ij} = [\alpha_{ij}, \beta_{ij}, \delta_{ij}] \quad (3)$$

$$A = [\tilde{a}_{ij}]$$

In the development analysis method, for each row of paired comparison matrix, the value of S_k, which is a triangular number, is calculated as Equation (4):

$$S_k = \sum_{j=1}^{n} M_{kj} * \left[\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right]^{-1} \quad (4)$$

k represents row numbers and also i and j respectively, represent options and indexes. In the method of development analysis, after calculations S_k, their magnitude degree to each other must be obtained. In general, if M_1 and M_2 are two triangular fuzzy numbers, the magnitude of M_1 to M_2, represented by $V(M_1 \geq M_2)$, is defined as Equation (5):

$$\begin{cases} V(M_1 \geq M_2) = 1 & if\ m_1 \geq m_2 \\ V(M_1 \geq M_2 = hgt(M_1 \cap M_2) & otherwise \end{cases} \quad (5)$$

It also has:

$$hgt(M_1 \cap M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)}$$

The magnitude of a triangular fuzzy number to other k triangular fuzzy number is obtained from Equation (6)

$$V(M_1 \geq M_2, \ldots, M_K) = V(M_1 \geq M_2), \ldots, V(M_1 \geq M_K) \quad (6)$$

Equation (7) is used to calculate the weight of indices in the pairwise comparison matrix:

$$W'(x_i) = Min\{V(S_i \geq S_k)\}, \qquad , k = 1,2,\ldots,n. \qquad k \neq i \quad (7)$$

Therefore, the weight vector of the indices will be as follows:

$$W'(x_i) = [W'(c_1), W'(c_2), \ldots, W'(c_n)]^T \quad (8)$$

This is the abnormal coefficients vector of the fuzzy hierarchical analysis process.

By means of Equation (9), the abnormal results obtained from Equation (8) are normalized. The normalized results obtained from Equation (9) are called W.

(9)

$$W_i = \frac{w_1'}{\sum w_i'}$$

The effects of interdependence between criteria are then determined. The relative dependence of the criteria is obtained by means of Equation (10), or in other words, by combining the results of the two previous steps. The combination of these is the FANP.

wc= B. W (10)

In this research, the FANP is fully used (ranking of options), which is the final weight obtained in the previous steps in the obtained preferences (the arithmetic mean of expert's opinions). The questionnaire for this section was a five-point Likert scale, as shown in Table 4. After multiplying the weight of each index by the arithmetic mean of the opinion's preference, the numbers obtained were then summed up in the columns of options. The result is the weight of each option which ultimately determines the top option (Dagdeviren and Yüksel , 2008).

Table 4. Specific weights for evaluating the internal correlation of criteria

Correlations	Very low	Low	Medium	High	Very high
Negative indicators	1	75.0	5.0	25.0	0
Positive indicators	0	25.0	5.0	75.0	1

3.2.2 DEMATEL Method

Step 1) Forming the Mean Matrix (Matrix A).

The formation of mean matrix is the first step after collecting questionnaires related to research factors.

Step 2) Calculating the impact matrix of unscaled direct relations (Matrix D).

At this step, by upscaling the mean matrix of expert opinions (Matrix A), the matrix of the effect of the unscaled direct relations is obtained.

Step 3) Calculating the total matrix (the total matrix of the direct and indirect influences).

Step 4) Calculating the indirect influence matrix (the total matrix of the direct and indirect influences).

To calculate the indirect influence matrix, one must first calculate the matrix $(I\text{-}D)^{-1}$ and matrix D^2.

Step 5) Impact and influence of factors relative to each other.

After calculating the matrix of the total relations, the sum of the rows and columns of the total matrix (that is indicating the degree of influence (D) and the impact (R) of each index) are calculated.

Step 6) Drawing a cause and effect diagram.

The D+R and D-R values must be obtained to form the cause and effect diagram. The values of D+R, which represent the horizontal axis of the cause-and-effect diagram, are known as the supremacy obtained through the sum of D and R. The importance and the sum of the intensity of an element are both influence and impact. Similarly, the vertical axis (D-R) represents the position of an element along the axis of the widths and is calculated by the difference between D and R. This position is definitely influence if the D-R value is positive and if it is negative it will definitely be impact.

R: The sum of the elements for each factor represents its influence on the other elements of the system under investigation.

D: The column sum of the elements for each factor represents the severity of impact of the factor mentioned above from the other elements of the system under consideration.

Parameters

M: Number of suppliers

PR: Number of products

PE: Number of periods

Djt: Demand for product j in period t

Wi: Weight of supplier i obtained from decision-making method

Cit: Supply capacity i in period t

Pij: Purchase price of supplier unit for product j

Oij: Supplier ordering cost i for product j

Hj: Maintenance cost per unit of product j

B: Very high numbers

λ_{ijt}: Environmental pollution due to shipping from a proposed supplier i^{th} to a product j^{th} in the period t
τ: Delivery time interval = 1

Decision variables

Xijt: Ordered amount to supplier i for product j in period t
Ijt: Product inventory j at the end of period t
Yijt: A binary variable for supplier i for product j in period t equal to 1, otherwise if supplier be selected it is 0.

Mathematical model

$$\text{Min } Z_1 = \sum_{i=1}^{M}\sum_{j=1}^{PR}\sum_{t=1}^{PE}(P_{ij}.X_{ijt} + H_j.I_{jt} + O_{ij}.Y_{ijt}) \quad 11$$

$$\text{Max } Z_2 = \sum_{i=1}^{M}\sum_{j=1}^{PR}\sum_{t=1}^{PE} W_i.X_{ijt} \quad 12$$

$$\text{Min } Z_3 = \sum_{i=1}^{M}\sum_{j=1}^{PR}\sum_{t=1}^{PE} \lambda_{ijt\tau}.X_{ijt} \quad 13$$

Hence:

$$\sum_{i=1}^{M} X_{ijt} + I_{jt-1} - I_{jt} = D_{jt} \qquad \forall j,t \quad 14$$
$$\sum_{i=1}^{PR}(X_{ijt}) \leq C_{it} \qquad \forall i,t \quad 15$$
$$X_{ijt} \leq BY_{ijt} \qquad \forall i,j,t \quad 16$$
$$X_{ijt} \geq 0 \qquad \forall i,j,t \quad 17$$
$$Y_{ijt} \in \{0,1\} \qquad \forall i,j,t \quad 18$$
$$I_{jt} \geq 0 \qquad \forall j,t \quad 19$$

The proposed model consists of three objective functions. In the first objective function, (Z_1) is minimized. The second objective function (Z_2) maximizes the weighted value of the quantity ordered by supplier i for the product in period t. Finally, the third objective function (Z_3) minimizes the amount of environmental pollution.

Equation 14 expresses the balance inventory in each period and for each product. Equation 15 ensures that suppliers' capacity must be respected. Equation 16 points out that delivery of products from suppliers is only done if selected supplier. Equations of 17, 18, and 19 represent the types of decision variables.

Due to the multi-objective mathematical model, each of the objectives is optimized as a single-objective and the ideal values of these objectives are then identified. These values are represented by the symbols Z_1_goal, Z_2_goal and Z_3_goal. In the next step, the sum of the difference of objectives from their ideal values is introduced and optimized as an ideal objective function.

4. Results

4.1 Investigating the Impact of Evaluation Criteria

Statistical T-test was used to evaluate the effectiveness of each of the evaluation criteria on suppliers in the supply chain of mega-projects. Based on the data obtained from the first questionnaire and using T-test, all 6 criteria were considered valid (since p-value of all criteria is less than 0.05). Descriptive statistics (Table 5) and inferential statistics (Table 6) for each of the criteria are shown in the following tables.

Table 5. Descriptive parameters of criteria affecting supplier evaluation

Criteria	N	Mean	Std. Deviation	Std. Error Mean
C1	30	3.3333	0.84418	0.15413
C2	30	3.4667	1.00801	0.18404
C3	30	3.4333	0.89763	0.16388
C4	30	3.4000	0.85501	0.15610
C5	30	3.4333	1.00630	0.18372
C6	30	3.4333	1.07265	0.19584

Table 6. The significance of criteria affecting supplier evaluation

Criteria	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
	Lower	Upper	Lower	Upper	Lower	Upper
C1	2.163	29	0.039	0.33333	0.0181	0.6486
C2	2.536	29	0.017	0.46667	0.0903	0.8431
C3	2.644	29	0.013	0.43333	0.0982	0.7685
C4	2.562	29	0.016	0.40000	0.0807	0.7193
C5	2.359	29	0.025	0.43333	0.0576	0.8091
C6	2.213	29	0.035	0.43333	0.0328	0.8339

The results of show that the selected criteria have a significant impact on the order allocation to the supplier in the supply chain of Iran Mall mega-projects.

4.2 Hierarchical Model of Research

The hierarchical model of the research is shown in Figure (2).

A comparative questionnaire was distributed among the statistical population based on the proposed hierarchical model, which is prioritizing and allocating orders to suppliers in the supply chain. The questionnaire was distributed among 31 Iran Mall project managers and staff, aimed to identify the criteria for selecting suppliers in the supply chain of mega-projects. The data collected from the questionnaire were used to prioritize suppliers in the supply chain of mega-projects using the combination of ANP and DEMATEL techniques.

According to demographic variables, most of the sample members (45%) are between 31 and 40 years of age. 84% of the sample are men. 62% of those with a bachelor's degree and 48% of respondents with a work experience of between 6 and 10 years.

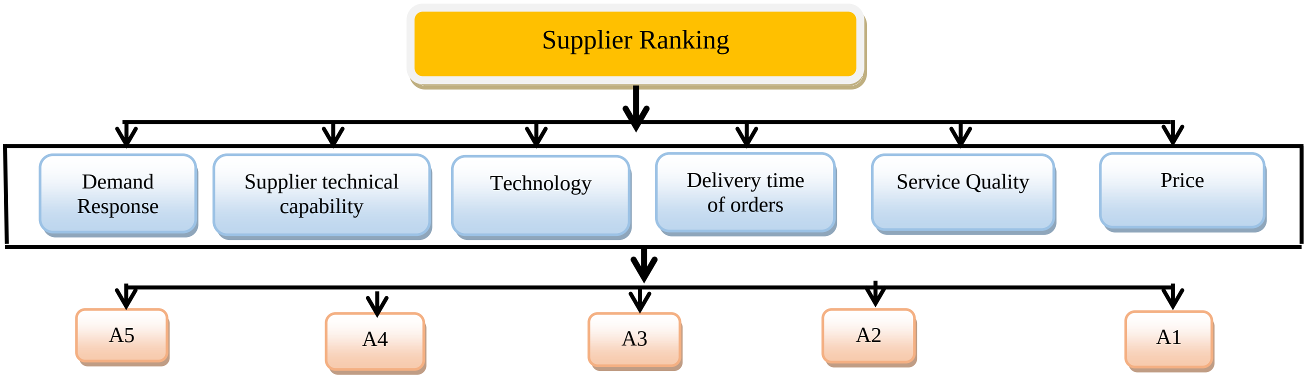

Figure 2. Hierarchical model of research

The list of suppliers and the criteria used to evaluate suppliers are as follows:
Supplier A.
Supplier B.
Supplier C.
Supplier D.
Supplier E.

List of evaluation criteria:
Price offered by supplier C1.
Service quality C2.
Delivery time of orders C3.
Technology used C4.
Supplier technical capability C5.
Demand response C6.

4.3 Findings of DEMATEL Technique

The research questionnaire was designed based on DEMATEL technique and distributed among the respondents. Table 7 shows the mean of the expert's opinion on the impact of each of the criteria in the row on the criteria in the column.

Table 7. Mean of expert's opinion

Mean of experts opinion	C1	C2	C3	C4	C5	C6
C1	0.000	0.000	2.250	3.120	3.740	1.580
C2	3.520	0.000	2.120	2.210	3.500	3.780
C3	1.000	1.000	0/000	1.250	0.000	1.200
C4	0.000	0.500	1.750	0.000	1.150	0.750
C5	3.120	2.800	2.210	2.610	0.000	3.640
C6	1.500	0.750	1.480	0.500	1.650	0.000

Equations (20) and (21) are used to normalize.

$$H_{ij} = \frac{z_{ij}}{r} \tag{20}$$

That r is obtained from the following Equation:

$$r = \max_{1 \le i \le n}\left(\sum_{j=1}^{n} z_{ij}\right) \tag{21}$$

Table 8 shows the normalized matrix.

Table 8- Normalized Matrix

Normalized Matrix	C1	C2	C3	C4	C5	C6
C1	0.000	0.000	0.149	0.206	0.247	0.104
C2	0.233	0.000	0.140	0.146	0.231	0.250
C3	0.066	0.066	0.000	0.083	0.000	0.079
C4	0.000	0.033	0.116	0.000	0.076	0.050
C5	0.206	0.185	0.146	0.173	0.000	0.241
C6	0.099	0.050	0.098	0.033	0.109	0.000

After calculating the above matrices, the total-relation fuzzy matrix is obtained according to formula (21).

$$T = \lim_{k \to +\infty} \left(H^1 + H^2 + \cdots + H^k\right) = H \times (I - H)^{-1} \tag{21}$$

In this Equation, I is unit matrix. The results of the calculation of the T matrix are shown in Table 9.

Table 9. Total Relation Matrix (T)

Total Relation Matrix	C1	C2	C3	C4	C5	C6
C1	0.150	0.114	0.309	0.352	0.368	0.279
C2	0.435	0.147	0.384	0.384	0.455	0.491
C3	0.126	0.099	0.076	0.148	0.082	0.150
C4	0.068	0.077	0.175	0.066	0.129	0.124
C5	0.394	0.290	0.371	0.384	0.244	0.461
C6	0.193	0.112	0.201	0.146	0.207	0.121

The next step is to obtain the sum of rows and columns of the matrix T. The sum of rows and columns is obtained by Equations (22) and (23).

$$(D)_{n\times 1} = \left[\sum_{j=1}^{n} T_{ij}\right]_{n\times 1} \tag{22}$$

$$(R)_{1\times n} = \left[\sum_{i=1}^{n} T_{ij}\right]_{1\times n} \tag{23}$$

That D and R are respectively matrices of $n \times 1$ and $1 \times n$.

The next step will determine the importance of criteria ($D_i + R_i$) and the relationship between criteria ($D_i - R_i$). If $D_i - R_i > 0$, the relevant criterion is influence and if $D_i - R_i < 0$ the relevant criterion is impact.

Table 10 shows $D_i + R_i$ and $D_i - R_i$.

Table 10. Gaining importance and influencing criteria

	Criterion	$D_i + R_i$	$D_i - R_i$
C1	Price offered	2.939	0.205
C2	service quality	3.134	1.457
C3	Delivery time of orders	2.197	-0.836
C4	Technology used	2.121	-0.840
C5	Supplier technical capability	3.631	0.660
C6	Demand Response	2.607	-0.647

Figure (3) shows the importance and impact and influence of the measures between the criteria. The horizontal axis of the graph denotes the importance of the criteria and the vertical axis, the impact or influence of the corresponding criteria.

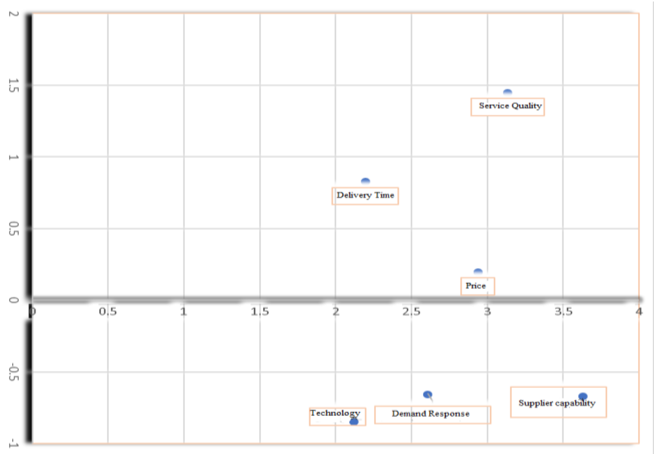

Figure 3. Causes and Effects of Criteria

In these relations, the influence will increase respectively with demand response, technical capability, technology, delivery time, price, service quality. The impact is also respectively higher due price, service quality and delivery time, and in the current state the technology will be lowered.

As seen in Figure (3), the price criteria provided by suppliers, services quality and products provided by suppliers, and the timing and manner of delivery of previous orders by suppliers are in the positive half of the causal diagram. As a result, they deem to be highly influential. The other three criteria, namely the technology and equipment used by the supplier, the technical capability of the supplier and the response to demand, are on the negative side of the diagram, indicating that these factors are less impact. Technical and response to demand is less.

4.4 Prioritizing suppliers in the supply chain with ANP techniques

In this section, prioritizing suppliers in the supply chain of mega-projects is done using ANP technique. The ANP process has four main steps:

Step 1: Model building

Based on the literature of similar research and studies and expert opinion, the model was developed as Figure 3.

Step 2: Pairwise Comparison Matrices and Priority Vectors

In ANP and AHP the decision elements in each combination are compared in terms of their importance with the control criteria and in pairs as well as in terms of their contribution to goal attainment. Relative significance values are determined by a scale of 1 to 9, with score 1 indicating the same importance between the two elements and score 9 indicating the extreme importance of the element being compared (matrix row) with another element (matrix column). The Mutual value is assigned to the inverse comparison and is such $a_{ij} = 1/a_{ij}$ that a_{ij} (a_{ji}) indicates the importance of the i^{th} (j^{th}) element in comparison to j^{th} (i^{th}) element. Pairwise comparisons in ANP are similar to AHP in the context of a matrix, and the local priority vector can be obtained by estimating the relative importance of each element (or component) being compared:

$$A \cdot w = \lambda_{\max} \cdot w \qquad (24)$$

That A is the Paired Comparison Matrix and w is Eigen Vector and $\lambda_{\max}$ is the largest Eigen value of A. Saaty (1980) proposed several algorithms for estimation w.

The super-matrix of this research will be as follows:

$$W_n = \begin{bmatrix} 0 & 0 & w_{13} \\ w_{21} & w_{22} & 0 \\ 0 & w_{32} & I \end{bmatrix}$$

Also, Table 11 is shown Normalized Matrix of Total relation (T).

Table 11. Normalized Matrix of Total relation (T)

Normalized value	C1	C2	C3	C4	C5	C6
C1	0.1098	0.1358	0.2038	0.2378	0.2478	0.1715
C2	0.3184	0.1752	0.2532	0.2594	0.3063	0.3019
C3	0.0922	0.1179	0.0501	0.1	0.0552	0.0922
C4	0.0497	0.0917	0.1154	0.0445	0.0868	0.0762
C5	0.2884	0.3456	0.2447	0.2594	0.1643	0.2835
C6	0.1412	0.1334	0.1325	0.0986	0.1393	0.0744

Step 3: Formation of Super matrix

The concept of super matrix is similar to a Markov Chain Process. In order to obtain the final priorities in a system affected by intrinsic dependencies, local priority vectors are proportionally inserted into the matrix columns, known as super matrix.

By normalizing each block of this so-called super matrix, the final priority of all matrix entry can be achieved. In this study, convergence was achieved by raising the matrix to 19.

Based on the boundary matrix, the weight of each supplier and the evaluation criteria are as follows:

Table 12. Weight of criteria

Criteria	Weight	Normalized weight
C1: Price offered by the supplier	0.1115	0.2228
C2: Service Quality	0.1161	0.2322
C3: Delivery Time of Orders	0.0765	0.1531
C4: Technology used	0.0577	0.1155
C5: Supplier Technical capability	0.0902	0.1805
C6: Demand Response	0.0478	0.0956

Based on the results of the Table 12, the priority weighting of the criteria for prioritizing the supplier evaluation criteria are: service quality, price offered by the supplier, delivery time of orders, technology used, supplier technical capability and demand response.

Table 13. Weight of suppliers

uppliers	Weight	Normalized weight
A1: First Supplier	0.0699	0.2805
A2: Second supplier	0.0577	0.2314
A3: Third supplier	0.0335	0.1343
A4: Fourth supplier	0.0882	0.3536
A5: Fifth supplier	0.0256	0.1452

Based on the results of Table 13, the prioritization of suppliers in the supply chain of Iran Mall construction projects is as follows:
Fourth supplier,
First supplier,
Second supplier,
Fifth supplier,
Third Provider.

4.5 Mathematical Model Solution Results

After designing the mathematical model, it was coded within the GAMS environment. There are 4 periods and 5 suppliers and 3 products to supply. The input data for this model are as follows. Table 14 shows the product demand for 4 periods. For example, the demand for product 1 in period 1 is 55, the demand of product 2 in period 1 is 50, and the demand of product 3 is 40.

Table 14. Product demand

Period	1	2	3	4
Demand of Product 1	55	50	50	40
Demand of Product 2	50	45	45	40
Demand of Product 3	40	35	35	30

Table 15 shows the environmental impact of products 1, 2 and 3 from each supplier in different periods. For example, for supplier 1 product 1 in period 1, the environmental impact is 0.4, and for supplier 5, product 1, 2 and 3 for period 1 is 0.9.

Table 15. Environmental impact

Period		1	2	3	4
Supplier 1	Product 1	0.4	0.3	0.2	0.1
	Product 2	0.4	0.3	0.2	0.1
	Product 3	0.5	0.4	0.3	0.2
Supplier 2	Product 1	0.9	0.8	0.7	0.6
	Product 2	0.8	0.7	0.6	0.5
	Product 3	0.8	0.7	0.6	0.5
Supplier 3	Product 1	0.7	0.6	0.5	0.4
	Product 2	0.8	0.7	0.6	0.5
	Product 3	0.8	0.7	0.6	0.5
Supplier 4	Product 1	0.6	0.5	0.4	0.3
	Product 2	0.5	0.4	0.3	0.2
	Product 3	0.5	0.4	0.3	0.2
Supplier 5	Product 1	0.9	0.8	0.7	0.6
	Product 2	0.9	0.8	0.7	0.5
	Product 3	0.9	0.8	0.6	0.5

Table 16 shows the purchase price of each product from 5 suppliers. The price of the product 1 from the supplier 1 is 5000, from the supplier 2 is 4500, from the supplier 3 is 4700, from the supplier 4 is 4800 and from the supplier 5 is 4500.

Table 16. Purchase Price

Supplier	1	2	3	4	5
Product 1	5000	4500	4700	4800	4500
Product 2	4200	4000	4100	4100	3900
Product 3	6000	5600	5700	5900	5600

Table 17 shows the capacity of suppliers for different periods. For example, supplier capacity 1 for period 1 is 17 and for period 4 is 13.

Table 17. Capacity of suppliers

Period	1	2	3	4
Supplier 1	17	20	16	13
Supplier 2	20	20	17	15
Supplier 3	20	20	18	15
Supplier 4	21	20	20	15
Supplier 5	17	16	16	14

After entering the case-study data into the GAMS software and coding the mathematical model, the optimal solution was obtained. Initially, each goal was optimized as a single objective and the optimal value of each objective was considered as its ideal objective. The ideal values for each objective are presented in Table 18.

Table 18. Ideal values for each of the objectives of the mathematical model

Objective Name	Symbol	Ideal Values
Cost	Z1_goal	1597100
Purchase Worth	Z2_goal	80.999
Reliability	Z3_goal	162.360

In the next step, the objective programming function is defined to minimize the sum of the difference of objectives from their ideal values and coded in GAMS software. The optimal solution is obtained after optimizing the objective programming model. Figure (4) is the GAMS output after implementing the ideal programming model.

```
Proven optimal solution.

MIP Solution:          35.530000    (104 iterations, 0 nodes)
Final Solve:           35.530000    (19 iterations)

Best possible:         35.530000
Absolute gap:           0.000000
Relative gap:           0.000000

--- Restarting execution
--- gams code.gms(148) 0 Mb
--- Reading solution for model goal
--- Executing after solve: elapsed 0:00:04.797
--- gams code.gms(149) 3 Mb
*** Status: Normal completion
--- Job gams code.gms Stop 11/02/18 02:03:50 elapsed 0:00:04.798
```

Figure 4. GAMS output of the ideal programming model

As shown in Figure 4, the GAP value of 0 is obtained, meaning that the GAMS software provided the optimal solution. The optimal value of the ideal objective function is also 35.53. Table 19 shows the values of each objective after solving the ideal model.

Table 19. The values of each objective function in the optimal solution of the ideal model

Objective Name	**Symbol**	**Objective Function Value**	**Difference with the Ideals**
Cost	Z1	1597100	0
Purchase Worth	Z2	75.389	5.61
Reliability	Z3	192.280	29.92
Total			35.53

As shown in Table 19, the output of the ideal objective function is exactly the same as the value of the first objective function, but the other objectives are far from their ideal. The reason for this is that the numerical value of the costs was much greater than the other objectives. On the other hand, as can be seen, the total of the difference of the objective functions with ideal is 35.53, which is exactly the value of the objective function in Fig. 6. Therefore, it can be concluded that GAMS software has been able to solve the ideal model correctly. Finally, quantity of order from selected suppliers is presented in Table 20.

Table 20. Quantity of order from selected suppliers

Product 1				
Supplier Period	1	2	3	4
1				
2	10	9	11	10
3	15	15	14	10
4				
5				
Product 2				
1				

2				
3	14	13	13	11
4	6	11	7	9
5				
Product 3				
1			8	
2	9	9	7.5	6.5
3	8.5	8.5	7.5	6
4	6.5	6.5	9	4.5
5				

5. Discussion and Conclusion

In order to increase competitive advantage, many companies consider the design and implementation of a proper SCM as an important and vital tool to utilize. In this situation, establishing the close- and long-term relationship between supplier and buyer is considered as one of the key factors of success in creating a supply chain. Therefore, the issue of selecting suppliers is the most important issue in the successful implementation of the supply chain.

According to the pertinent literature, and in order to resolve existing research gaps, this research aims at developing a hybrid approach of multi-criteria planning and goal programming to evaluate, prioritize and allocate orders to suppliers in the supply chain of mega-projects. FANP and DEMATEL technique were utilized upon which suppliers were prioritized based on influential indicators in this field. Then, using goal programming, order allocation was made to suppliers. T-test was used to verify the research hypotheses. The results showed that with 95% confidence and error level less than 0.05, there is a significant relationship between variables of price, quality of services and products, time and manner of delivery of previous orders, technology and equipment used by suppliers in evaluating and assigning order to supplier in supply chain of mega-projects are impressive. In the next section, prioritization and allocation of orders to suppliers in the supply chain of mega-projects as well as the ranking of the prioritization of selected suppliers were determined by criteria. The results of data analysis show that criteria ranking by weight and their importance in prioritizing and allocating orders to suppliers in the supply chain of mega-projects are as follows:

1. Quality of service, 2. Price offered by supplier, 3. Delivery time, 4. Technology used, 5. Supplier's technical capability and 6. Demand response

Also, based on the results, the prioritization of the suppliers is:

1. The fourth supplier, 2. The first supplier, 3. The second supplier, 4. The fifth supplier, 5. The third supplier.

The results of this study are quite comparable to other studies cited in the literature. In Abbaszadeh Tavasoli et al. (2018) the aim was to evaluate and select suppliers with QFD method and ELECTRE in the quality management system. The results of their research indicated that the index and related strategies of the supplier are the least significant relationships, as well as the resource earned the lowest weight, and the highest rank was given to design and growth. Also, Liou et al. (2014) showed that the structure of the relationships among the criteria and the criteria weights developed using DEMATEL combined with ANP called DANP. They presented supplier evaluation criteria as follows: compatibility, quality, cost, risk.

6. Implications of the Research

Considering the results obtained from the ANP-DEMATEL integrated method, which indicates the importance of the of service quality and products provided by suppliers in the evaluation and allocation of orders to suppliers in the supply chain of mega-projects over other factors. It is recommended that the selection of suppliers be given higher priority over the quality index of services and products provided by suppliers. Supplier can use the proposed approach to benchmark, to progress possibility of selection and to develop better products and processes. The results can help managers to select the best supplier among the candidates.

Given that prices are also one of the issues in prioritization, so when the supply chain is larger, it leads to better control over cost variability. Using such an expert system, random, independent, and evenly distributed project demands are merged by suppliers into a larger group. The time factor and how suppliers deliver previous orders are in the third ranking of importance in term of influencing the evaluation and allocation of orders to suppliers in the supply chain of mega-projects. The amount of corporate attention to this issue should naturally be less than the first two factors. Managers can align the needs and inventory of the warehouse, using the capabilities of the information technology system, organize customer information, suppliers and processes to send orders in the shortest time and with the best quality to customers. The hence, it is also better to use more suppliers to reduce delays as well as costs.

7. Limitation and Future Research

The hybrid of the two methods improves the reliability of the results. Current work has some limitations. This study provides an evaluation framework for selecting suppliers and applies it to practical case, but it is not widely used for the time being. Also, due to the limitations, this work has been done in an uncertain environment, which can be determined certain using the fuzzy method. For further researches also, optimization approach can be employed by adjusting parameters of fuzzy basis function. Modeling using fuzzy sets has proven to be an impressive way for formulating decision problems, where the information available is subjective and imprecise. Fuzzy numbers stand for a specific range for a certain value (Shukla et al., 2014). In addition to, for the two methods of DEMATEL and ANP, the application of this study will result in the difficulty of data processing in the case of many alternative suppliers and many evaluation criteria. Researches will make innovations using the methods in future researches, making them more convenient, intuitive and effective, and the results more precise, so as to progress the application of the framework. For further researches in the scope of supplier selection for megaproject, BWM and MULTIMOORA methods can be used for weighting and ranking of suppliers (Sarabi and Avakh Darestani, 2020).

References

Abbaszadeh Tavassoli, M., Avakh Darestani, S. and Abbaszadeh Tavassoli, S. (2018). “Supplier selection and evaluation using QFD and ELECTRE in quality management system environment (case study: Faravari & Sakht Company)”, *Int. J. Productivity and Quality Management*, Vol. 24 No. 1, pp. 84-100.

Amid, A. Ghodsypour, S. H. and O’Brien, C. (2011). “A weighted max–min model for fuzzy multi-objective supplier selection in a supply chain”. *International Journal of Production Economics*, Vol. 131 No. 1, pp. 139-145**.**

Aouadni, S., Aouadni, I. and Rebaï, A. (2019). “A systematic review on supplier selection and order allocation problems”, *Journal of Industrial Engineering International*, Vol. 15, pp. 267–289.

Asadabadi, M.R. (2017). “A customer based supplier selection process that combines quality function deployment”, the analytic network process and a Markov chain”, *European Journal of Operational Research*, Vol. 263 No. 3, pp. 1049-1062.

Asadi, Y. and Zagardi, S.H. (2008). “A Model for Performance Evaluation and Supplier Selection in Supply Chain Using Balanced Score card (Case Study: Iran Khodro Industrial Group)”, 6th International Management Conference, Tehran, Ariana Research Group, Iran.

Asfora Frej, E., Roselli, L.R. P., de Almeida, J. A. and de Almeida, A.T. (2017). “A Multicriteria Decision Model for Supplier Selection in a Food Industry Based on FITradeoff Method”, *Mathematical Problems in Engineering,* pp. 1-9

Ávila, P., Mota, Alzira., Pires, A., Bastos, J., Putnik, G and Teixeira, J. (2012). “Supplier’s selection model based on an empirical study”, *Procedia Technology*, Vol. 5, pp. 625 – 634

Azimifard, A., Moosavirad, S.H. and Ariafar, Sh. (2018). “Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods”, *Resources Policy*, Vol. 57, pp. 30-44.

Baccarini, D. (1996). “The concept of project complexity—A review”, *Int. J. Project Manage*, Vol. 14 No. 4, pp. 201–204.

Biranvand, H., Ghazanfari, M and Sahebi, H. (2016). “Profitability Analysis of Crude Oil Supply Chain Assuming Uncertainty in Market Demand and Prices, with Scenario-Based Optimization Approach: A Case Study for Iran”, International Conference on Industrial Engineering and Management, Tehran, Iran.

Bottani, E. and Rizzi, A. (2012). “A fuzzy TOPSIS methodology to support outsourcing of logistics services”. *Supply Chain Management: An International Journal*. Vol. 11 No. 4, pp. 294-308 .

Chang, A., Chih, Y.Y., Chew, E. and Pisarski, A. (2013). “Reconceptualising mega project success in Australian Defence: Recognising the importance of value co-creation”, *International Journal of Project Management*, Vol. 31, pp.1139–1153.

Chang, B., Chang, C. W. and Wu, C. H. (2011). “Fuzzy DEMATEL method for developing supplier selection criteria”. *Expert systems with Applications*, Vol. 38 No. 3, pp. 1850-1858.

Cheraghi, S.H., Dadashzadeh, M., Subramanian, M. (2011). “Critical Success Factors for Supplier Selection: An Update”, *Journal of Applied Business Research*, Vol. 20 No. 2, pp. 91-108.

Dagdeviren, M., Yüksel, İ. (2008). “Developing a Fuzzy Analytic Hierarchy Process (AHP) Model for Behavior-Based Safety Management”, *Information Sciences*, Vol. 178 No. 6, pp.1717-1733

Dickson, GW. (1966). “An analysis of vendor selection: systems and decisions”. *Journal of Purchasing*, Vol. 1, pp. 5–17.

Du, B., Guo, S., Huang, X., Li, Y. and Guo, J. (2015). “A Pareto supplier selection algorithm for minimum the life cycle cost of complex product system”. *Expert Systems with Applications*, Vol. 42 No. 9, pp. 4253-4264 .

Eamon, B. M. (1998). “Supply chain design and analysis: Models and methods. International journal of production economics”, Vol. 55 No. 3, pp. 281-294 .

Efendigil, T., Önüt, S. and Kongar, E. (2013). “A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness. Computers & industrial engineering”. Vol. 54 No. 2, pp. 269- 287 .

Eriksson, P. E., and Pesämaa, O. (2013). “Buyer-supplier integration in project-based industries”, *J. Bus. Ind. Marketing*, Vol. 28 No. 1, pp. 29-40.

Farshchian, Gh., Avakh Darestani, S. and Hamidi, N. (2020). “Developing a decision-making dashboard for power losses attributes of Iran’s electricity distribution network”, *Energy*, pp. 1-18.

Fawcett, S. E., Ellram, L. M., and Ogden, J. A. (2014). Supply chain management: from vision to implementation. Pearson Education .

Flyvbjerg, B. (2014). What You Should Know About Megaprojects and Why: An Overview, *Project Management Journal*, Vol. 45 No. 2, pp.1-30.

Ghodsypour, S. H., and Obrien, C. (2010). “the total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraints”. *International Journal of production economics*, Vol. 73 No. 1, pp. 15-27.

Golpîra, H. (2020). “Optimal integration of the facility location problem into the multi-project multi-supplier multi-resource Construction Supply Chain network design under the vendor managed inventory strategy”, *Expert Systems with Applications*, Vol. 139, pp.1-12.

Govindan, K., Kannan, D. and Haq, A. (2010). “Analyzing supplier development criteria for an automobile industry”. *Industrial Management and Data Systems*. Vol. 110 No. 1, pp. 43-62.

Hamdan, S., and Cheaitou, A. (2017). “Supplier selection and order allocation with green criteria: An MCDM and multi-objective optimization approach”. *Computers & Operations Research*. Vol. 81, pp. 282-304 .

He, Q., Luo, L. Hu, Y. P.C. and Chan, A. (2015). “Measuring the complexity of mega construction projects in China—A fuzzy analytic network process analysis, International Journal of Project Management”, Vol. 33, pp. 549–563.

Ho, W., Xu, X. and Dey, P. K. (2010). “Multi-criteria decision making approaches for supplier evaluation and selection: A literature review”. *European Journal of Operational Research*. Vol. 202 No. 1, pp. 16-24 .

Hosseini, R. (2012). “Evaluation and Selection of Suppliers in the Supply Chain Using Fuzzy Multi Criteria Decision Making Techniques”, MSc thesis, Azad University. Iran.

Houston, J. R. (2014). “Complex infrastructure projects made simple.” Conference: Pipelines, ASCE, Reston, VA, pp. 358–366.

Keskin, G.A. (2015). “Using integrated fuzzy DEMATEL and fuzzy C: means algorithm for supplier evaluation and selection”, *International Journal of Production Research*, Vol. 53 No. 12, pp. 1-18.

Kokangul, A. and Susuz, Z. (2009). “Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount”. *Applied mathematical modelling*, Vol. 33 No. 3, pp. 1417-1429 .

Kreng, V. and Wang, I.C. (2005). “Supplier management for manufacturer - A case study of flexible PCB”. *The International Journal of Advanced Manufacturing Technology*. Vol. 25. pp. 785-792.

Lee, A. H. (2009). “A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks”, *Expert systems with applications*, Vol. 36 No. 2, pp. 2879-2893 .

Liang, R. and Chong, H. Y. (2019). “A hybrid group decision model for green supplier selection: a case study of megaprojects”, *Engineering, Construction and Architectural Management*, Vol. 26 No. 8, pp. 1712-1734

Liou, J.J.H., Chuang, Y. and Tzeng, G. (2014). “A fuzzy integral-based model for supplier evaluation and improvement”, *Information Sciences*, Vol. 266, pp. 199-217.

Locatelli, g., Mikic, M., Kovacevic, M., Brookes, N. and Ivanisevic, N. (2017). The Successful Delivery of Megaprojects: A Novel Research Method, Project Management Journal, Vol. 48 Issue. 5, pp. 78-94.

Mahmoudi, A., Deng, X., Javed, S. A. and Zhang, N. (2020). “Sustainable Supplier Selection in Megaprojects: Grey Ordinal Priority Approach”, *Bus Strat Env*. pp. 1–22.

Najar Vazifehdan, M., Avakh Darestani, S. (2019). “Green Logistic Outsourcing Employing Multi Criteria Decision Making and Quality Function Deployment in The Petrochemical Industry”, *the Asian Journal of shipping and logistic*, Vol. 35 No. 4, pp. 243-254.

Penadés-Plà, V., García-Segura, T., V. Martí, J. and Yepes, V. (2016). “A Review of Multi-Criteria Decision-Making Methods Applied to the Sustainable Bridge Design”, *Sustainability*, Vol. 8, No. 12, pp. 1-21.

Prasanna Venkatesan S., and Goh, M. (2016). “Multi-objective supplier selection and order allocation under disruption risk”. *Transportation Research Part E: Logistics and Transportation Review*. Vol. 95, pp. 124-42 .

Qu, G., Zhang, Zh., Qu, W. and Xu, Z. (2020). “Green Supplier Selection Based on Green Practices Evaluated Using Fuzzy Approaches of TOPSIS and ELECTRE with a Case Study in a Chinese Internet Company”, *Int. J. Environ. Res. Public Health*, Vol. 17, pp. 1-32.

Razmi, J., and Nasrollahi, M. (2013). Green Supply Chain, Qazvin Azad University Press, First Edition, Iran.

Saaty, T.L. (1980). The Analytic Hierarchy Process. McGraw-Hill, New York.

Saaty, T.L. (1996). Decision Making with Dependence and Feedback: The Analytic Network Process. RWS, Pittsburgh.

Sajadieh, M. and Akbari, M.R. (2008). “Principles of Supply Chain Management”, Adine Publications, Second Edition, Iran.

Sarabi, E.P and Darestani, S.A. (2020). “Developing a decision support system for logistics service provider selection employing fuzzy MULTIMOORA & BWM in mining equipment manufacturing”, *Applied Soft Computing Journal*, doi: https://doi.org/10.1016/j.asoc.2020.106849.

Sarkis, J. and Talluri, S. (2008). “A model for strategic supplier selection”. *Journal of supply chain management*, Vol. 38 No. 4, pp. 18-28 .

Senvar, O., Tuzkaya, G., and Kahraman, C. (2014). “Multi criteria supplier selection using fuzzy PROMETHEE method. In Supply Chain Management Under Fuzziness. Springer Berlin Heidelberg .

Sevkli, M., Lenny Koh, S. C., Zaim, S., Demirbag, M., and Tatoglu, E. (2008). “Hybrid analytical hierarchy process model for supplier selection”. *Industrial Management & Data Systems*, Vol. 108 No. 1, pp. 122-142

Shaw, K. Shankar, R. Yadav, S. S. and Thakur, L. S. (2012). “Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain”. *Expert Systems with Applications*, Vol. 39 No. 9, pp. 8182-8192 .

Si, Sh.L., You, X-Y., Liu, H.Ch. and Zhang, P. (2018). “DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications”, *Mathematical Problems in Engineering*, Vol. 2018 No.1, pp.1-33.

Suraraksa, J. and Kwang, S. Sh. (2019). “Comparative Analysis of Factors for Supplier Selection and Monitoring: The Case of the Automotive Industry in Thailand”, *Sustainability*, Vol. 11, pp. 1-19.

Wang, L. Chu, J. and Wu, J. (2007), “Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process”. *International Journal of production economics*, Vol. 107, pp. 151-163 .

Wang, T.Y. and Yang, Y.H. (2009). “A fuzzy model for supplier selection in quantity discount environments”. *Expert Systems with Applications*, Vol. 36, pp. 12179–12187

Wang, X., Chong, H-Y. and Kwak, Y. (2017). “Supply Chain Management in Megaprojects”. *Journal of Management in Engineering*. Vol. 33 No. 4, pp. 02017001.

Weber, C. A. and Ellram, L. M. (2009). “Supplier selection using multi-objective programming: a decision support system approach”. *International Journal of Physical Distribution & Logistics Management*, Vol. 23 No. 2, pp. 3-14 .

Zazulina, M. (2010). “Strategic Approach to Purchasing Management in Small & Medium Size Enterprise (Focus on Supplier Selection and Supplier Development Functions)”, Master’s Thesis in Logistics and Innovation Management. university of Gavle, Sweden.

Shukla_, R.K., Garg, D. and Agarwal, A. (2014). “An integrated approach of Fuzzy AHP and Fuzzy TOPSIS in modeling supply chain coordination”, *Production & Manufacturing Research*, Vol. 2 Issue.1, pp. 415-437.